

CEMENT AND CEMENT MANUFACTURE

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Japanese Portland Cement Association.

A NUMBER of papers on cement, read at the 1930 meeting of the Japanese Portland Cement Association, are printed in a report of the meeting just published. Abstracts of some of the papers are given in the following:

Testing by Small Plastic Mortar Briquettes.

Professor Minoru Hamada said the standard method of testing cement by 1:3 mortar is not a real guide to the properties of cement as the principal compound of concrete. There is a formula which may be applied for the relation between the strength of mortar and that of concrete prepared from ordinary Portland cement as follows: $S = \frac{2.2 \times K}{20_x}$, where S is the strength of concrete tested wet at the age of

28 days, using cylindrical specimens of 15 by 30 cm., K is the compression strength of standard mortar at 28 days, and x is the water-cement-ratio of the concrete. This formula is, however, not applicable to Portland cement which has been exposed to weathering or to iron Portland and blast-furnace cements. The author proposes a new method of testing cement, based on (1) the use of a mortar of equal water-cement-ratio to that of concrete, and (2) the use of small plastic mortar briquettes. Equal water-cement-ratio would yield equal strength both for the mortar and concrete, while by testing small plastic mortar briquettes (cylinders 2 cm. diameter and 4 cm. height) will simplify the operation of testing.

The results of the author's experiments indicate that the new method is advantageous, especially in view of the fact that it gives uniform results irrespective of the kind of cement, of its age, and of the water-cement-ratio.

Slag-Aluminous Cement.

Mr. Yosomatsu Shimizu said the new slag-aluminous cement is a mixture of aluminous cement and blast-furnace slag, the proportions of which depend on the chemical composition of the compounds. These should be ascertained by determining the strength and other physical properties. The strength of this new cement is comparable to that of aluminous cement, being greater than that of ordinary iron Portland cement and of blast-furnace cement, and has, in addition, a higher resistance against corrosive waters. The aim in manufacturing slag-aluminous cement is the development of the latent hydraulic properties of the slag used. The usual mechanical and thermal tests fail when applied, with the result that

the method of measuring electrical conductivity has been used, and accurate results have been obtained with regard to the times of setting and hardening. The suitable mixing proportion has been determined also by this method.

Japanese Portland Cement Clinkers.

Mr. Jiro Matsuura said: Thirty specimens of Japanese clinker were examined petrographically to identify the principal compounds according to the classification of Törnebohm (Alit, Belit, Celit, and Glass). When these results were compared with those of other investigators, the minerals found in Japanese clinker were identical. When clinker was burnt in the laboratory it was noted that, by using naturally occurring raw materials and applying high temperatures up to 1,500 deg. C., distinct crystallization and change from Belit into Alit were obtained.

Mixing Aluminous and Portland Cements.

Mr. K. Koyanagi said: Hydration of aluminous cement takes place according to the chemical reaction $2(\text{CaO} \cdot \text{Al}_2\text{O}_3) + 11\text{H}_2\text{O} = 2\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 8\text{H}_2\text{O} + 2\text{Al(OH)}_3$, while the hydration of aluminous cement with an addition of calcium hydrate as a product of the hydration of Portland cement takes place according to the chemical equation $\text{CaO} \cdot \text{Al}_2\text{O}_3 + \text{Ca(OH)}_2 + 7\text{H}_2\text{O} = 2\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 8\text{H}_2\text{O}$.

The first reaction is initially a very slow one which accelerates in a later stage, while the second reaction begins at once, thus giving rise to quick-setting.

Mill Lining Plates.

Mr. Eiichiro Itami said: Tests made to compare chilled cast iron with various manganese steels resulted in the decision that lining plates made of manganese steel can be used in a thickness of about two-thirds of that of chilled iron plates. Accordingly the weight of the mill and power consumption can be reduced. It was also determined that impact resistance of manganese steel is higher than that of chilled iron.

Calorific Value of Powdered Coal.

Mr. Kikuriro Nagase said the calorific value of each load of coal arriving at the coal plant was determined, and it was found that the calorific value was far higher than that of the dried and powdered coal. The loss during drying and grinding amounted to an average of 5 per cent. of the total calorific value. Research showed that the loss was experienced especially in the drying and separating department. With regard to the high content of volatile matter in Japanese coals, it is recommended that special care should be taken when drying the coal and that the coal be ground without any separating machinery.

Other papers were read by Y. Ikeda on the safety movements of the Onoda plant, Onoda Cement Co., Ltd., and by S. Nagaya on the relation between the fineness modulus of aggregate and the strength of concrete.

The late Mr. C. Spackman.

The death is announced of Mr. Charles Spackman, of Rosehaugh, Clitheroe, who was the owner of the Isis Cement Works, Clitheroe, and who was well known as a cement chemist. During the War Mr. Spackman experimented with the use of cement for the lining of steel furnaces, and he was consulted by Government Departments on several occasions. Mr. Spackman, who was 84 years of age, was a Fellow of the Institute of Chemistry, and in earlier life owned cement works in Leicestershire.

The Theory of the Rotary Kiln.

By RUDOLF ZOLLINGER.

It is rare that the opportunity arises of stopping a rotary kiln in full commission. Yet such an experiment is valuable in that it gives useful information regarding the burning process and the conditions in the different zones of the kiln. No two kilns work in the same way, and every raw material behaves differently in burning. Reactions take place between coal-ash, kiln lining, and raw materials, and give rise to different local effects. A knowledge of these factors repays the works manager, and enables him to predict and guarantee the quality of the cement he produces.

It recently became necessary to stop a kiln at full output, and the author availed himself of the opportunity thus offered to study the conditions in the kiln from the above points of view. The kiln was 210 ft. long, and its diameter 6 ft. 6 in., and 8 ft. in the clinkering zone. The raw materials were marl of the Jura formation from the so-called Effinger deposits, mixed with a certain amount of limestone. The fuel was a mixture of equal parts bituminous and semi-bituminous coals, the mixture giving 20.6 per cent. volatile matter and 9.8 per cent. ash. It was ground to 11 per cent. on the 180 sieve. The percentage analysis of the coal-ash was 44.2-44.8 SiO₂, 37.5-40.0 R₂O₃, approximately 4 SO₃, and 10 CaO+MgO, and 3-4 alkalis. Portland cement of high initial strength was aimed at, and the strengths attained were

	lb. per sq. in.	lb. per sq. in.
At 3 days, crushing strength	5,700,	tensile 425
At 7 days,	7,100,	455
At 28 days,	8,500,	570

The raw material was prepared on the following basis:

SiO₂, 12.34 per cent. (0.45 per cent., or 3.65 per cent. of the total SiO₂, was soluble).

R₂O₃, 5.39 per cent. (1.38 per cent., or 25.6 per cent. of the total Al₂O₃, was soluble).

CaO, 43.98 per cent. (calcimeter value 76.5 per cent.).

MgO, 0.77 per cent.

SO₃, nil.

Loss on ignition, 36.98 per cent.

Difference, 0.54 per cent.

Lime-modulus, 2.48.

Silicate-modulus, 2.29.

It is obvious that a very high lime-modulus was adopted, and the following considerations will show that this was necessary. Theoretically, a cement of the following composition would be obtained:

	Per cent.
SiO ₂	19.58
R ₂ O ₃	8.55
CaO	69.79
MgO	1.22
Difference	0.86

The cement actually obtained had, however, the following composition:

	Per cent.
SiO ₂	19.80
Insoluble residue	0.12
Loss on ignition	1.12
R ₂ O ₃	9.42
CaO	67.26
MgO	1.50
SO ₃	0.59
Difference	0.20
Lime-modulus	2.30
Silicate-modulus	2.10

From this, the following constituents must be eliminated as non-cementitious substance:

	Per cent.
Insoluble residue	0.12
MgO	1.50
Difference	0.20
CaCO ₃	2.50
CaSO ₄	1.00

Total 5.32

A cement substance of the following composition remains:

	Per cent.
SiO ₂	20.91
R ₂ O ₃	9.94
CaO	69.14
Lime-modulus	2.24
Silicate-modulus	2.10

According to the formula of Kühl, $\text{CaO} = 2.8 \text{ SiO}_2 + 1.1 \text{ Al}_2\text{O}_3 + 0.7 \text{ Fe}_2\text{O}_3$, the amount of CaO required is, since the raw meal is practically free from iron, $2.8 \times 20.91 + 1.1 \times 9.94 = 69.48$ per cent. Comparing this with the value 69.14 found in the cement-substance, the difference is so small that it may be accepted that the cement is correctly proportioned. This correct proportioning was only rendered possible by knowledge of the conditions in the kiln. The stopping and the resultant study of the kiln, although they brought forth nothing new, afforded a further proof of the correctness of the method of working.

As already pointed out, a comparison of the theoretical cement and that actually obtained emphasises the extremely high lime-modulus of the raw meal. If the theoretically calculated cement were actually obtained this high modulus would doubtless lead to an unsound cement. The analysis of the coal-ash was known, however, and taken into account. SiO₂ and R₂O₃ from the ash are taken up by the raw materials. The two compounds are so related that they give a silicate-modulus of about 1.00, and as a result the silicate-modulus of the cement must be reduced. Similarly the gain in SiO₂ and R₂O₃ must result in a lowering of the lime-content, and thus of the lime-modulus, since the gain in CaO from the coal-ash is relatively small. If the effect of the coal-ash had not been allowed for, the cement obtained would have had a lime-modulus 2.05; it would thus have been too low in lime and of entirely different properties from those required.

The proportioning of the raw meal was thus known from practical experience to be correct and to allow for the absorption of coal-ash, but it was considered desirable further to confirm this by comprehensive investigation of the kiln. In

TABLE I.

CEMENT MATERIAL.

the first place, samples of the material in the kiln were taken at intervals of 2 metres and analysed. Next, all rings which had formed in the kiln were similarly sampled at 2-metre intervals and analysed. In Table I the results of these analyses are summarised, while Fig. 1 is an exaggerated diagram of the thickness of the various ring deposits. It is seen that, apart from the ring of burnt material (clinker ring) immediately at the kiln mouth, the main ring commences 14 m. from the mouth and extends to 20 m. It is also evident that the lime-content of the rings increases on proceeding towards the kiln mouth; i.e., the coal-ash gives up SiO_2 and R_2O_3 to the cement mass. This is also shown by the fact that the lime-modulus of the cement material tends to become lower on nearing the kiln mouth. The reaction of the coal-ash is further definitely

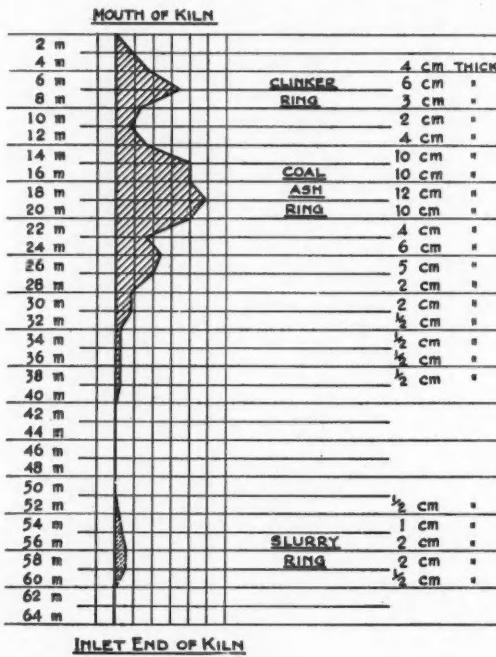


Fig. 1.

shown by the continuous increase in the SO_3 -content of the material in passing down the kiln.

Fig. 2 offers an additional proof that calcination and the opening up of the material do not proceed one after the other, but simultaneously, i.e., the lime begins to react with the clay as soon as it is formed from the CaCO_3 . This is shown by the analogous course of the three curves, which further indicate that the reaction with R_2O_3 both commences and finishes earlier than the reaction between lime and silica. It is also seen that one-third of the kiln is used solely for drying, and that only in the middle third do calcination and the opening up of the material spontaneously set in. Last, it is found that these reactions are practically complete 10 metres from the kiln mouth.

The analyses of the rings show that the clinker ring at the kiln mouth consists essentially of cement material, the clinkering temperature of which has been lowered by the absorption of SiO_2 from the coal-ash, with the result that the material has softened and adhered to the kiln. The composition of this first ring, distant about 4 m. from the kiln mouth, is very striking. The high proportion of insoluble SiO_2 and R_2O_3 shows that at this point the silica-rich cement mass must have reacted with the kiln lining, while the high SO_3 content proves that the coal-ash plays a part in the reactions, as already stated. Thus, this first ring originates from secondary reactions. In the first place, the absorption of SiO_2 from the coal-ash gives rise to compounds of lower clinkering temperature, which then fuse and attack the lining.

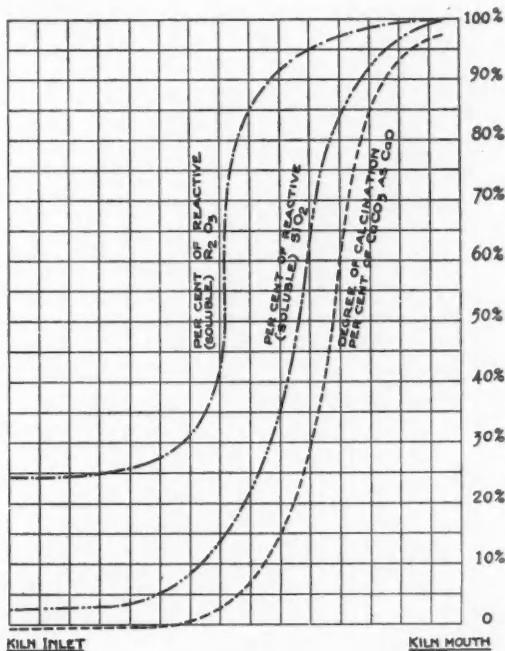


Fig. 2.

It is interesting, also, that the coal-ash appears to take up MgO . While the coal-ash ring in the hinder part of the kiln is free from MgO , the MgO -content increases on proceeding towards the kiln mouth, until it is actually greater than that of the cement.

The sulphur in the coal-ash appears to undergo a cycle of changes. The raw slurry is free from SO_3 . The ring formations in the cooler parts of the kiln contain high proportions of SO_3 , which decrease towards the kiln mouth. It would appear that sulphur is evaporated in the hot zones of the kiln and deposited in the cooler portions. Further, a reducing action appears to be involved in this process, since the ring deposits in the cooler parts of the kiln contain a high proportion of sulphide in addition to SO_3 . It is probable the

SO₃-content of the slurry ring is at a maximum when the kiln is hot, and becomes less on cooling, which further indicates the existence of a sulphur cycle. The temperature in the higher parts of the kiln is inadequate to maintain sulphur in the form of vapour sufficiently for it to pass into the stack. If it were otherwise, SO₃ deposits and the consequent slurry rings could not be formed. This draws attention to the danger inherent in the use of excessively long kilns, viz., that, although they give better fuel economy, they directly favour the formation of slurry rings.

If the cement raw materials were incapable of reacting with the coal-ash, rings of immense size would rapidly be formed in the kiln. We thus see the danger of paying insufficient attention to the coal-ash, and the necessity for adjusting the raw mix so that it is in itself able to destroy coal-ash rings. This can be done by so proportioning the raw material that it can abstract the SiO₂ and R₂O₃ from the ring. In practice, this means that the lime-modulus of the raw mix must be boldly raised to a sufficiently high value, and the comparison between the raw mix, the theoretical clinker, and the clinker actually obtained, shows that this method is correct and without danger.

The correct silicate-modulus may be obtained by trial. As already shown, this factor is also affected by the coal-ash, and must be adjusted to be higher than appears necessary. In acting upon this rule, however, care must be taken that the resulting product does not clinker at too low a temperature and attack the kiln lining.

Canadian Cement Output.

The production of cement in Canada in 1931 is given as 10,017,331 barrels. This compares with 11,032,538 barrels in 1930.

Danish Cement Exports.

The exports of cement from Denmark in 1931 were 151,844 tons. This compares with 315,059 tons in 1930 and 465,430 tons in 1929.

Cement Sales in Germany.

The sales of the Deutscher Zement Bund for the month of January, 1932, are stated to be 104,000 tons. The corresponding figures for January, 1931 and 1930, are 164,000 tons and 315,000 tons respectively.

United States Cement Production and Sales.

The production of Portland cement for the months of January, 1931 and 1932, is given by the United States Bureau of Mines as 6,595,000 barrels and 4,989,000 barrels respectively, a decrease of 24 per cent. The sales are given as 4,692,000 barrels in 1931 and 3,363,000 barrels in 1932, a decrease of 28 per cent.

Belgian Cement Output.

The output of cement in Belgium for the month of January, 1932, was 83,000 tons, or 25 per cent. of total capacity. This compares with 120,000 tons, or 36 per cent. of capacity, in January, 1931.

French Cement Companies' Dividends.

Société Coloniale des Chaux et Ciments Portland de Marseille has paid a dividend of 12 per cent. gross for the year 1931, the same as for 1930. The net profits for these two years were 4,583,751 francs (£36,903) and 4,827,324 francs (£38,864) respectively.

Société des Ciments de Neuville-sur-Escaut reports a trading profit of 1,190,600 francs (£9,585) for 1931, which compares with 1,287,900 francs (£10,368) in 1930.

Cement Imports in Latvia.

We understand that the quantity of cement allowed to be imported into Latvia during 1932 has been fixed at 2,350 tons.

The Effect of Storage on Cement.

THE following notes on the effect of storage conditions on the properties of cement are taken from the latest report of the Building Research Board:

The investigation of the effect of storage conditions on the properties of cement, although not yet complete, has proceeded far enough for certain general conclusions to be drawn. It is possible that experiments now in hand will necessitate modifications of the statements made here; nevertheless, the results are of considerable general interest, and it is felt advisable to communicate them in this unfinished form.

The investigation has been divided into two sections. The first was a full-scale investigation covering a range of cements, containers, and conditions of storage. The large number of factors examined in the course of this investigation necessarily limited the number of tests actually made in each case considered. The second section was therefore designed to fill, in greater detail, gaps in the first section where information appeared particularly desirable. Broadly speaking, the first section of the investigation showed that storage was equivalent, as would be anticipated, to a slow aeration, and the second section has concentrated on the effect of aeration on the rapidity of hardening of cements.

The following factors were investigated:—Type of cement: (a) Normal Portland; (b) Rapid-hardening Portland; (c) Aluminous. Type of container: (a) Jute sack; (b) Four-ply paper sack; (c) Wooden keg; (d) Metal drum. Condition of storage: (a) Closed shed storage at normal temperatures; (b) Cold storage at -10 deg. C.; (c) Oven storage at $+70$ deg. C. Period of storage: A standard period of three months was taken for all cases, with additional periods up to two years in some cases.

For each of these the following properties have been examined: (1) Loss on ignition; (2) appearance; (3) water requirements for standard consistency; (4) fineness (sieves and air separator); (5) setting time (initial and final); (6) specific gravity; (7) strength of neat cement ($1:3$ mortars and $1:2:4$ concretes at various ages); and (8) the condition of containers.

The conditions of storage were selected to represent conditions which might occur in practice. The shed storage may be regarded as typical of a contractor's cement store. The oven storage is representative of the extreme form of hot storage, as, for example, in the hold of a ship. The cold storage was taken as an extreme case of what might happen to cement stored during a hard winter. Following the various periods of storage, portions of the cement were set aside and tested after aeration in trays in layers about 2 in. deep for periods of about one month. Before sampling, each container or each tray was emptied on to a board and the cement thoroughly mixed by hand.

The general conclusions that may be drawn from the results of the tests are as follows:—

(1) For all types of cement tested, and all containers used except the metal drum, the loss on ignition has been found to increase as a result of storage. The effect appears, in fact, to be equivalent to a slow aeration process, and aeration for a comparatively short time in an open tray will produce results similar to those obtained by storing cement for much longer periods in a non-airtight container. It appears, then, that the increase in loss on ignition is a fair guide to the deterioration of the cement during storage. Provided the loss on ignition is less than 2 per cent., the Portland cement examined was not found to be seriously damaged by aeration. This figure is conservative, and it is

probable that the loss on ignition may increase to nearly 4 per cent. for a rapid-hardening Portland cement before the rapidity of hardening is seriously affected. An aluminous cement will frequently show a gain and not a loss on ignition due to the oxidisation of ferrous iron. This gain on ignition decreases during storage, but very slowly. The deterioration in the cement is also slow.

(2) As a result of the more severe types of storage (for example, the jute and paper sacks in the shed), the cement appeared coarser to the touch, and in some cases air-set lumps were formed.

(3) The amount of water required to make up a neat cement paste of standard consistency rose steadily with increasing loss on ignition.

(4) There appeared to be no change in the fineness of the cement, except where the residue of a No. 180 sieve was increased by the presence of air-set lumps. The flour content as determined with an air separator remained unaffected for all samples.

(5) The setting time of cement was not always affected in the same manner or to the same extent by storage. For example, in the case of aluminous cement it appeared that the setting time lengthened, the final setting time for some samples increasing from 6 hours to 11 hours. The Portland cement samples stored in the oven, with the exception of that stored in a metal drum, developed a flash set which did not disappear until the cement had undergone several months' further aeration in open trays. Although Portland cements stored in metal drums in the oven did not develop a flash set during actual storage, when the cement was taken from the drum and aerated in open trays it developed a flash set within three days. The aluminous cement stored in the oven did not develop a flash set. The setting times of the other samples of Portland cement seemed to fluctuate during aeration without having a definite trend in either direction.

(6) The specific gravity of all samples appeared to decrease as the loss on ignition increased, and these changes were roughly proportional.

(7) There seems to be no doubt that the ultimate effect of storage is not so much a deterioration of the strength developed in the concrete as a decrease in the rate of attaining that strength. The second section throws more light on this matter.

(8) With regard to the type of container tested, from the point of view of the protection afforded to the cement, there seems to be little to choose between the four-ply paper sack and the jute sack. The wooden keg seems rather better than either of these, and the air-tight metal drum is definitely best of all. If cement be stored in air-tight drums for all practical purposes it does not alter, and, if subsequent aeration be avoided, may be used with confidence even if it has been in the drum for over a year. The more easily the atmosphere may reach the cement the more quickly the cement will deteriorate.

The ordinary jute and paper sacks and even the wooden kegs were not capable of withstanding such a high temperature as 70 deg. C. for any length of time. The sacks split and the fabric became so friable that it was difficult to remove them from the oven; the hoops dropped off and the wood staves fell apart as soon as the kegs were disturbed. In the case of the rapid-hardening Portland cement, the disintegration of the paper sack took place within a week of its being placed in the oven.

The second section of the investigation is intended primarily to give information about the influence of aeration on the rapidity of hardening of cements. At the same time, an attempt is being made to determine the relative influence of the various factors which take part in the process of aeration.

Table 1.—Effect of Storage on Cement.

Period of Aeration.	Loss on Ignition, CO ₂ Content.	Per cent.	Water Requirement for Normal Consistency.	Setting Times.	Tensile Strength of Neat Cement.			Tensile Strength of 1 : 3 Sand Mortars.			Crushing Strength of 1 : 2.4 Concrete.											
					Initial.	Final.	H. M.	Lb./sq. in.	1 day	3 days	7 days	14 days	28 days	90 days	1 day	3 days	7 days					
None (as received)	0.82	0.08	22.5	1.35	3.05	414	675	721	677	679	205	372	410	464	511	599	415	1,150	1,720	2,280	2,970	4,240
7	2.07	0.65	22.5	2.15	3.25	227	510	724	687	696	118	331	407	471	539	579	270	1,110	1,930	2,490	3,270	4,650
25	3.79	1.43	23.5	4.0	5.45	165	373	529	600	653	106	249	327	410	465	—	110	605	1,160	—	2,310	—
80	5.90	3.28	25.0	1.45	1.50	111	254	450	559	—	51	140	273	382	—	—	65	295	800	1,400	—	—
(1) ORDINARY PORTLAND CEMENT.																						
None (as received)	1.56	0.52	25.0	1.50	2.20	502	843	950	924	991	372	500	559	—	647	623	856	2,630	3,890	—	4,770	5,780
14	2.60	1.06	26.0	2.50	3.35	515	754	924	940	949	371	526	635	609	651	677	1,160	3,260	4,340	5,270	5,290	6,280
48	4.95	2.89	26.0	—	—	383	534	688	722	714	227	420	557	581	685	666	170	1,990	3,740	—	5,220	5,900
94	8.00	4.91	28.5	1.10	2.20	216	459	595	668	597	138	316	425	557	588	625	170	990	2,330	3,340	4,220	—

Water/cement ratio for concrete.
 (1) Ordinary Portland
 (2) Rapid-hardening Portland

Water content calculated from B.S.S. equation $P/4 + 2.5$ where P is water content for neat cement, i.e., requirement for normal consistency.
 All above results are means of 6 tests.

The cements are exposed for aeration in open trays in a room where temperature and humidity conditions are fairly steady. Tests have so far been made on normal Portland and rapid-hardening Portland cements only. The results agree in general with the earlier investigations, and have supplemented the information about the change in rate of hardening. A summary of the results is given in Table I. It will be seen that aeration has a very important influence on the rate of hardening, and that after considerable aeration the strengths of the rapid-hardening Portland cements at early ages actually fall below the initial strengths of the normal Portland cements. Similarly the normal Portland cements show a decreased rate of hardening. The ultimate strengths appear comparatively unaffected, however, and even with a loss of ignition of as much as 8 per cent. the rapid-hardening Portland cement produces a strong concrete at 28 days.

The loss on ignition is again shown to be an indication of the deterioration of the cement, and it is clearly important that when tests on concrete cannot be made the quality of a rapid-hardening Portland cement should be judged with due consideration to the loss on ignition. It should be borne in mind that, provided the loss on ignition does not exceed the limiting value (3 per cent.) stipulated by the British Standard Specification, there is little probability of serious deterioration having occurred.

The attempt to determine the relative influence of the various factors which take part in the process of aeration has not yet proceeded far. Cements are being stored, for this investigation, in atmospheres of CO_2 , moist air, and CO_2 with moist air.

Punjab Portland Cement Company.

The Punjab Portland Cement Co., Ltd., reports a net profit of 1,89,738 rupees (£14,233) for the year ending September 30, 1931. This compares with 1,93,752 rupees (£14,535) for the year ending September 30, 1930.

Swedish Cement Company's Dividend.

Skanska Cement A/B. reports a net profit of 1,787,329 Kr. (£98,475) for 1931, and proposes to pay a dividend of 12 per cent. This compares with a net profit of 2,177,189 Kr. (£119,955) in 1930 when the same rate of dividend was paid.

German Cement Companies' Dividends.

Portland-Cementwerk Saxonia A.G., formerly Klein Laas Söhne, has declared no dividend for 1931, when the net profit was 54,654 marks (£2,732). A dividend of 5 per cent. was paid in 1930, when the net profit was 89,000 marks (£4,450).

A dividend of 4 per cent. has been declared by Portlandcement-und-Kalkwerke Elsa A.G. for 1931. This compares with 7 per cent. in 1930. The net profit for these two years was 116,254 RM. (£5,812) and 240,701 RM. (£12,035) respectively.

Bonner Bergwerks-und-Hutten-Verein A.G. has passed its dividend for 1931, as it did in 1930.

Finkenberg A.G. für Portland-Cement und Wasserkalk Fabrikation has passed its dividend for 1931; a dividend of 6 per cent. was paid in 1930.

Vereinigte Harzer Portland-Cement-und-Kalkindustrie has passed a dividend for 1931; 5 per cent. was paid in 1930.

Württembergisches Portland-Cement-Werk Zu Lauffen a/Necker reports a net profit of 519,372 RM. (£25,968) for 1931, and proposes to pay a dividend of 8 per cent. The net profit for 1930 was 584,398 RM. (£29,219), when a dividend of 10 per cent. was paid.

Heat Economy in the Cement Industry.—III.

By Dr. HANS BUSSMEYER.

The Rotary Kiln (continued).

TABLES X, XI, and XII summarise the results of United States and German kiln tests, the former carried out privately and the latter by the German Kiln Commission.¹¹

In the United States tests, data on the CO_2 content of the kiln gases are lacking so that the excess air used in burning cannot be estimated; for the purpose of the calculations $\lambda = 1.3$ is assumed. Further, no values of the moisture content of the raw meal are given for the experiments of Table X, and the value $b = 2$ per cent. = 31.5 kg. per 1,000 kg. clinker is adopted throughout. The total losses, a , are obtained by difference from the experimental data.

All the tests agree in showing that the total losses calculated from the measured gas temperature t_g as a percentage of the total heat used are much higher for the dry than for the wet process. This is explained by the fact that the errors of temperature measurement in the dry process are much higher than in the wet process. In the case of the United States kilns, only the temperature results of test No. 6 of Table X and No. 5 of Table XI are reasonably reliable.

In the German wet process tests the best temperature value is given by test No. 3. The temperature in test No. 2 should have been higher, and test No. 1 was not further considered for reasons not given in the original report. The German dry process tests Nos. 1 and 2 can be submitted to an additional check, since the kilns are run in conjunction with waste-heat boilers.

In test No. 1, 473,345 kcal. per 1,000 kg. clinker are recovered in the steam developed by the waste-heat boiler. The available heat in the kiln gases, calculated from the temperature, amounts to 552,140 kcal., so that the efficiency of the waste-heat boiler must be 85.5 per cent. On leaving the waste-heat plant the gases had a temperature of 232 deg. C. If the excess air factor λ be assumed to increase only from 1.18 to 1.3 in the waste-heat boiler this would account for a loss of 195,000 kcal. from the kiln gases, so that these must contain at least $473,345 + 195,000 = 668,345$ kcal. Assuming the loss from the boiler by radiation, conduction, etc., to be only 4 per cent. of the heat recovered (*i.e.*, 19,000 kcal.), the value 687,345 kcal. is obtained for the heat content of the kiln gases. This gives 880 deg. C. for the temperature of the gases. The total losses, a , thus fall to 26.9 per cent., and the efficiency of the boiler becomes 68.8 per cent.

In test No. 2 the waste-heat boiler recovered 560,983 kcal. per 1,000 kg. clinker as steam, the corresponding efficiency being 88.7 per cent. On emerging from the boiler the gases were at 251 deg. C. From these assumptions it is determined that 233,300 kcal. are lost from the gases, and the loss from the steam plant by radiation, etc., is 22,500 kcal. The heat content of the kiln gases is thus 816,780 kcal. and the temperature t_g about 975 deg. The boiler efficiency is 68.6 per cent., and the total losses, a , are 459,500 kcal., or 27 per cent. of the total heat consumption.

A number of attempts have been made to divide the total losses, a , into separate items, and by computing these individually to arrive at a value for a independent of waste-gas temperature measurements. In the first place, the residual heat in the clinker may be separated. Using a good cooler, the clinker can be cooled to below 150 deg. C. Taking this temperature as the average the

¹¹ E. Schott. *Zement*, Vol. 15, p. 881, 1926; Vol. 17, p. 1,198, 1928.

TABLE X.
UNITED STATES ROTARY KILNS. DRY PROCESS.

Plant No.	1	2	3	4	5	6
Diameter of kiln metres	3.04	2.43	2.43	1.975	3.04	2.43
Length of kiln	45.5	33.5	33.5	18.2	45.5	30.5
Heat consumption per 1,000 kg. clinker kcal.	1,957,500	1,968,400	2,073,200	2,103,300	2,324,840	2,376,900
Coal consumption kg.	261	262.4	276.4	280.4	310	316.9
Water content of raw material	2	2	2	2	2	2
Exit gas temperature deg. C.	675	650	760	730	706	815
Output Q tons	184	103	143	51	218	91
Theoretical heat consumption kcal.	420,000	420,000	420,000	420,000	420,000	420,000
Evaporation of water	18,740	18,740	18,740	18,740	18,740	18,740
Available heat in exit gases	789,060	745,250	952,460	918,000	944,150	1,353,400
Totals	1,227,800	1,183,990	1,391,200	1,356,740	1,382,890	1,792,140
Total losses a_1 , by difference kcal.	729,700	754,410	682,000	746,560	941,950	584,760
Total losses, a percentage	37.3	39.8	32.9	35.5	40.5	24.6
Sum of $a_1 + a_2$ per cent.	4.0	4.6	4.0	5.0	3.3	3.8
a_3 by difference "	33.3	35.2	28.9	30.5	37.2	20.8

TABLE XI.
UNITED STATES ROTARY KILNS. WET PROCESS.

Plant No.	1	2	3	4	5	6
Diameter of kiln metres	2.43	3.04/2.74	2.43	3.04/2.74	3.04/2.74	3.04
Length of kiln	38	51.5	33.5	51.5	71.5	73
Heat consumption, per 1,000 kg. clinker kcal.	1,970,300	2,092,300	2,251,800	2,281,500	2,288,740	2,311,000
Coal consumption kg.	263	279	300	304	305	308
Water content of raw slurry	31.0	33.5	32.0	31.0	34.5	37.0
Exit gas temperature deg. C.	485	400	510	485	620	485
Output Q tons	104	166	101	174	186	246
Theoretical heat consumption kcal.	420,000	420,000	420,000	420,000	420,000	420,000
Evaporation of water	414,000	464,000	434,000	414,000	489,000	543,000
Available heat in exit gases	700,200	630,000	819,000	775,200	1,031,500	840,700
Totals	1,584,200	1,514,000	1,673,000	1,609,200	1,940,500	1,803,700
Total losses, a_1 , by difference kcal.	386,100	578,300	578,800	672,300	348,240	507,300
Total losses, a percentage	19.6	27.6	25.8	29.4	15.2	22.0
Sum of $a_1 + a_2$ per cent.	4.5	3.9	4.0	3.5	3.4	3.2
a_3 by difference "	15.1	23.7	21.8	25.9	11.8	18.8

TABLE XII.
TESTS BY THE KILN COMMISSION OF THE ASSOCIATION OF GERMAN PORTLAND CEMENT MANUFACTURERS.

Process.	I. Dry process.			II. Wet process.		
	1	2	3	1	2	3
Plant No.						
Diameter of kiln metres	3.2	3.2	2.5/2.1	3.0	3.0	2.7
Length of kiln	54.6	54.6	50	60	60	50
Heat consumption, per 1,000 kg. clinker kcal.	1,517,880	1,698,930	1,911,250	1,907,050	2,262,435	2,287,610
Coal consumption kg.	202.4	226.5	254.8	254.8	301.7	305.0
Excess air, λ	1.18	1.18	1.30	1.28	1.15	1.15
Water content	0.3	0.3	11.4	41.5	41.5	40.5
Exit gas temperature deg. C.	726	757	409	381	503	551
Output Q tons	225.2	199.3	114.9	102.2	222.2	198.6
Theoretical heat consumption kcal.	420,000	420,000	420,000	420,000	420,000	420,000
Evaporation of water	2,770	2,650	119,000	681,800	635,000	628,000
Available heat in exit gases	552,140	632,430	774,400	596,500	826,000	902,000
Totals	974,910	1,055,080	1,913,400	1,698,380	1,881,000	1,950,000
Total losses, a_1 , by difference kcal.	542,970	643,850	597,850	206,670	381,435	337,610
Total losses percentage	35.8	37.7	31.2	11.0	16.8	14.7
Sum of $a_1 + a_2$ per cent.	4.9	4.5	4.5	4.0	3.4	3.4
a_3 by difference "	30.9	33.2	26.7	7.0	13.4	11.3

specific heat of the clinker is found to be 0.195 from Hartner's curve, and 1,000 kg. thus contain 29,250 kcal. With a heat consumption 7,500x kcal. (referred to standard coal) the loss of heat in the clinker, expressed as a percentage of the heat consumption, is

$$a_1 = 100 \times \frac{29,250}{7,500x} = \frac{390}{x} \quad \dots \dots \dots \quad (16)$$

It is seen that a_1 becomes less as x increases, and, as x varies from 200 to 320 kg., a_1 varies from 1.95 to 1.22 per cent., or, taking the average, it amounts to 1.6 per cent. of the total heat used.

Loss of heat from the kiln and cooler by radiation, conduction, and convection forms another important fraction of the total losses a . The heat given up to its surroundings by a tube l metres long and of D metres external diameter is

$$q = \pi D l \beta (t_e - t_s) \text{ kcal. per hour} \quad \dots \dots \dots \quad (17)$$

where t_e is the temperature of the external surface and t_s of the surroundings in deg. C., while β is the heat emission of 1 square metre of external surface per 1 deg. C. of surface temperature per hour.

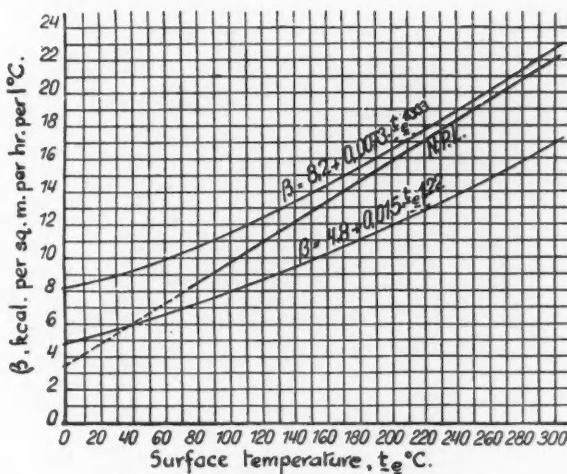


Fig. 10.—Radiation from a Heated Tube.

Nusselt¹² has given the following formula for β :

$$\beta = 1.02 \frac{(t_e - t_s)}{D} + \frac{C}{t_e - t_s} \left[\left(\frac{T_s}{100} \right)^4 - \left(\frac{T_e}{100} \right)^4 \right] \text{ kcal. per 1 deg. C. per sq. m. per hour.} \quad (18)$$

T_e and T_s are the absolute temperatures corresponding to t_e and t_s , and C is the radiation constant. The influence of D on β is small, so that, for values of D from 1.5 to 3.0 m., C may be taken as 4 and t_s as 0 deg. C. with close approximation. The following more convenient equation is thus obtained:

$$\beta = 4.8 + 0.015 t_e^{1.22} \quad \dots \dots \dots \quad (19)$$

¹² Schack and Rummel. *Mitt. Wärmestelle Düsseldorf*, No. 51, 1923.

As a result of recent researches Schack¹³ presents the following equation, which gives higher values than (19):

$$\beta = 8.2 + 0.0073t_e^{1.333} \dots \dots \dots \quad (20)$$

Experiments carried out at the National Physical Laboratory¹⁴ (England) on a tube 4 ft. long and of 9 in. diameter, internally heated electrically, gave results which can be expressed from 80 deg. C. upwards by the formula

$$\beta = 3.5 + 0.062t_e \dots \dots \dots \quad (21)$$

Formulae (19), (20), and (21) are represented graphically in Fig. 10.

Formulæ (19) to (21) are derived from experiments on tubes of small diameter. Since β diminishes as the diameter D increases, these formulæ probably give too high values for tubes of such large diameters as the kiln and cooler. On the other hand, it must be remembered that the experiments were carried out on motionless horizontal cylinders in still air, and that the kiln and cooler are rotating and slightly inclined, and are situated in spacious sheds or even frequently in the open, so that vigorous air movements are possible. Further, their surfaces are not smooth, but are considerably increased by the presence of butt-straps and rivets, tyres, gear ring, etc. Undoubtedly an appreciable quantity of heat is conducted *via* the tyres into the kiln foundations, which makes it necessary further to increase the values given by the formulæ.

Assuming that periodic measurements of surface temperature are made at regular distances along the entire length of the kiln or cooler, a mean value $(\beta t_e)_m$ can be calculated which gives the heat loss by radiation in 24 hours to be

$$24\pi DL(\beta t_e)_m \text{ kcal.}$$

If Q is the output of clinker per 24 hours, the radiation loss per 1,000 kg. clinker is

$$24\pi \frac{DL}{Q} (\beta t_e)_m \text{ kcal.}$$

Since the heat consumption per 1,000 kg. clinker is $7,500x$ kcal. (referred to standard coal), the following expression is obtained for the heat loss from cooler or kiln (a_2 or a_3), expressed as a percentage of the total heat consumption:

$$a_2 \text{ (or } a_3) = \frac{100 \times 24 \times \pi}{7,500} \times \frac{DL}{Qx} (\beta t_e)_m \text{ per cent.,}$$

for which may be written

$$a_2 \text{ (or } a_3) = \frac{DL}{Qx} (\beta t_e)_m \text{ per cent.} \dots \dots \dots \quad (22)$$

The average output of the cooler under favourable conditions may be taken to be 2.0 tons clinker per 24 hours per cubic metre of overall volume. The length L_c may be taken as 12 times the diameter, whence

$$Q = 2.0 \times \frac{\pi}{4} \times 12 \times D_c^3 = 6\pi D_c^3,$$

or

$$D_c = 0.376 \sqrt[3]{Q},$$

whence

$$a_2 = \frac{1.697(\beta t_e)_m}{x \sqrt[3]{Q}} \text{ per cent.}$$

TABLE XIII.
PERCENTAGE VALUES OF a_2 (HEAT LOSS FROM COOLER) FOR VARIOUS VALUES OF x AND Q .

Q tons.	100.			200.			300.			
	x kg.	200	275	350	200	275	350	200	275	350
a_2 ..	4.04	2.94	2.31	3.21	2.34	1.83	2.80	2.04	1.60	

¹³ Schack. *Stahl u. Eisen*, p. 1,298, 1928.

The average surface temperature (t_e) of the cooler, measured over the entire surface, rarely exceeds 140 deg. C. If necessary, it can be arranged so that this temperature is not exceeded by increasing the brick lining or by placing a layer of insulating material between the lining and shell. From equation (20) we find for $t_{em} = 140$ deg. C. the value $\beta = 13.4$, and $(\beta t_e)_m = 1,875$ kcal. per sq. m. per hour. Thence

$$\alpha_2 = \frac{3,180}{x \sqrt[4]{Q}} \text{ per cent.}$$

To this must be added an allowance for the increase of surface due to the departure of the cooler from a true cylinder and for the surface of the constructional parts between kiln and cooler; 18 per cent. is ample for this, so that finally

$$\alpha_2 = \frac{3,750}{x \sqrt[4]{Q}} \text{ per cent.} \quad (23)$$

Thus for average conditions α_2 may be taken as 2.6 to 2.8 per cent., and the total heat loss due to the cooling of the clinker, $\alpha_1 + \alpha_2$, as 4.5 per cent. of the entire heat consumption. Tables X to XII give the sum $\alpha_1 + \alpha_2$ calculated from equations (16) to (23), and α_3 is obtained by subtracting this from α .

The loss α_3 from the kiln is considerably more difficult to determine than the loss α_2 from the cooler. The expression DL/Qx of equation (22) represents that fraction of the surface of the kiln that may be considered as being at the disposal of each kilogramme of standard coal over a period of 24 hours. It is thus a measure of the forcing of the kiln, inasmuch as a kiln must be regarded as being the more highly loaded as DL/Qx is smaller. It is obvious that the output, Q , the specific fuel consumption, and the external dimensions of the kiln must be in some way interrelated. On the other hand, Q and x are influenced by many variables, of which the following are a few: Inclination and period of rotation of the kiln; moisture content of the raw meal or slurry; efficiency of the heat exchange between secondary air and clinker; excess air; draught, etc. As a result of this, experimental results give an extremely wide range of values of DL/Qx .

Many attempts have been made to determine the average surface temperature of a rotary kiln. It must not be forgotten, however, that it is very difficult to make such measurements on a kiln in service. It is only recently that instruments have been evolved that are capable of making these measurements with reasonable accuracy. In addition, there is the fact that we are not dealing with a smooth surface, so that to begin with there is a considerable uncertainty in the value of β , at any rate for the conditions of the rotary kiln. Further, extremely different values of surface temperature will be obtained on the same kiln at different times, since the measurements are greatly affected by the state of the kiln lining and the thickness of the ring accretions at the time of measurement. Finally, the conductivity of the lining material affects the results, a factor which has up to the present received very little attention, importance having been placed rather on refractory properties and resistance to chemical attack. The determination of the radiation losses from kiln and cooler has been dealt with by W. Gilbert in articles in *CEMENT AND CEMENT MANUFACTURE* for 1930.¹⁴

The quantity $(\beta t_e)_m$ for a number of the cases in Tables X to XII has been calculated from equation (22) for various values of α_3 , and the results are given in Table XIV. This Table also gives the values α obtained by adding to α_3 the sum $(\alpha_1 + \alpha_2)$ from Tables X to XII, with the exit gas temperature t_g found by calculation from α ; the values t_{em} calculated from equation (20) are also recorded. Certain examples in which the kiln has an enlarged zone are ignored, since the original paper does not give the relative lengths of different diameters.

¹⁴ Gilbert. *Cement and Cement Manufacture*, Vol. 3, p. 948, 1930.

TABLE XIV.
VALUES OF $(\beta t_e)_m$, SURFACE TEMPERATURE t_{em} AND EXIT GAS TEMPERATURE OF ROTARY KILN.

Example.	Table X.—No. 1.	Table X.—No. 2.				Table X.—No. 3.				Table X.—No. 4.			
		0.00288				0.00301				0.00206			
DL/Qx	10	15	20	25	10	15	20	25	10	15	20	25	
a_3 per cent.													
$(\beta t_e)_m$ kcal.	3,480	5,220	6,050	8,600	3,330	5,000	6,660	8,320	4,860	7,300	9,720	12,120	
t_{em} deg. C.	207	260	300	338	199	254	294	330	250	309	359	404	
a per cent.	14.0	19.0	24.0	29.0	14.6	19.6	24.6	29.6	14.0	19.0	24.0	29.0	
t_g deg. C.	1,080	903	910	825	1,105	1,050	995	940	1,115	1,030	945	920	
Example.	Table X.—No. 5.				Table X.—No. 6.				Table XI.—No. 1.				
DL/Qx	0.00252				0.00205				0.00258				
a_3 per cent.	10	15	20	25	10	15	20	25	10	15	20	25	
$(\beta t_e)_m$ kcal.	3,970	5,960	7,950	9,950	4,890	7,330	9,780	12,200	3,880	5,820	7,760	9,700	
t_{em} deg. C.	224	278	322	363	254	309	360	405	220	275	318	358	
a per cent.	15.0	20.0	25.0	30.0	13.3	18.3	23.3	28.3	13.8	18.8	23.8	28.8	
t_g deg. C.	1,090	1,000	920	835	1,180	1,095	1,010	925	1,180	1,095	1,005	920	
Example.	Table XI.—No. 3.				Table XI.—No. 6.				Table XII.—No. I. 2.				
DL/Qx	0.00340				0.00268				0.00292				
a_3 per cent.	10	15	20	25	10	15	20	25	10	15	20	25	
$(\beta t_e)_m$ kcal.	2,950	4,220	5,890	7,360	3,740	5,600	7,470	9,340	3,430	5,150	6,860	8,580	
t_{em} deg. C.	187	232	276	310	216	270	312	351	206	258	299	330	
a per cent.	14.5	19.5	24.5	29.5	14.0	19.0	24.0	29.0	13.2	18.2	23.2	28.2	
t_g deg. C.	592	525	455	390	680	610	540	470	605	540	475	405	
Example.	Table XII.—No. II. 2.				Table XII.—No. II. 3.				Table XII.—No. II. 2.				
DL/Qx	0.00388				0.00245				0.00222				
a_3 per cent.	10	15	20	25	10	15	20	25	10	15	20	25	
$(\beta t_e)_m$ kcal.	2,580	3,870	5,160	6,450	4,000	6,140	8,170	10,300	4,520	6,770	9,020	11,250	
t_{em} deg. C.	170	220	258	290	228	283	327	388	240	297	345	387	
a per cent.	14.5	19.5	24.5	29.5	13.4	18.4	23.4	28.4	13.4	18.4	23.4	28.4	
t_g deg. C.	1,090	1,000	910	820	550	480	410	340	565	495	425	355	

Table XIV shows that a_3 lies in general between 10 and 15 per cent., and that the sum a amounts to between 14 and 22 per cent. of the heat consumed, allowing a small addition for smaller losses not here investigated and for variations in practical conditions. The higher value of 22 per cent. corresponds to slightly forced dry-process kilns with a coal consumption $x=180$ kg., while the lower value of 14 per cent. corresponds to strongly forced wet-process kilns, with $x=320$ kg.

With these figures as a basis we are able to calculate heat balances for various values of x , i.e., for kilns forced to a greater or less extent, and these are set forth in Tables XV and XVI. In deriving these Tables it is assumed that the relation between falling a and increasing x is linear, and that a is in general somewhat lower for the wet process than for the dry. In order to indicate how the various total losses a are distributed among a_1 , a_2 , and a_3 , the Tables give a_1 and a_2 calculated from equations (16) and (23) for $Q=200$ tons, a_3 being obtained by difference. The dry process results are calculated with moist raw meal, $b=10$ per cent. For the wet process the heat balances are calculated for different water contents to show the influence of water content, b , on the exit gas temperature, t_g , and on the heat available in the exit gases.

The following considerations are of special interest in studying the wet process. Large quantities of water are evaporated, and it is seen from Table XVI that for $b=38$ per cent., 565,250 kcal. per 1,000 kg. clinker are used for the

TABLE XV.
HEAT BALANCES FOR THE DRY PROCESS.

Coal consumption	..	..	..	..	x kg. kcal.	200 1,500,000	220 1,650,000	240 1,800,000	260 1,950,000
Heat	"	"	"	"	per cent.	21	20	19	18
Total losses, α	..	..	..	..	kcal.	420,000 315,000	420,000 330,000	420,000 342,000	420,000 351,000
Theoretical heat requirement	..	..	..	..	kcal.	420,000 315,000	420,000 330,000	420,000 342,000	420,000 351,000
Total losses, α	..	..	..	..	"
Total heat in exit gases	..	..	..	..	kcal.	735,000	900,000	1,038,000	1,179,000
Heat of evaporation of water	..	..	..	..	"	102,340	102,340	102,340	102,340
Available heat in exit gases	..	..	..	..	"	662,660	797,660	935,660	1,076,660
Exit gas temp., t_g for $\lambda = 1.2, b = 10$	..	..	..	..	deg. C.	715	810	870	935
Distribution of total losses α :-									
Loss in clinker a_1	..	..	..	..	per cent.	1.95	1.77	1.62	1.50
Loss from cooler a_2 ($Q = 200$)	..	..	..	..	"	3.21	2.82	2.52	2.26
Loss from kiln and residual loss	..	..	..	..	"	15.84	15.41	14.86	14.24

TABLE XVI.
HEAT BALANCES FOR THE WET PROCESS.

Coal consumption	..	..	..	..	x kg. kcal.	240 1,800,000	260 1,950,000	280 2,100,000	300 2,250,000	320 2,400,000
Heat consumption	..	..	..	..	kcal.	1,800,000	1,950,000	2,100,000	2,250,000	2,400,000
Total losses, α	..	..	..	..	per cent.	18	17	16	15	14
Theoretical heat requirement	..	..	..	..	kcal.	420,000	420,000	420,000	420,000	420,000
Total losses, α	..	..	..	..	"	324,000	331,500	336,000	337,500	336,000
Total heat in exit gases	..	..	..	..	"	1,056,000	1,198,000	1,344,000	1,492,000	1,644,000
$b=36$ per cent. { Heat of evaporation .. kcal.						519,500	519,500	519,500	519,500	519,500
{ Available heat in exit gases .. kcal.						536,500	670,000	824,500	973,000	1,124,500
{ Temp. t_g of exit gases for $\lambda=1.2$.. deg. C.						400	480	550	620	675
$b=38$ per cent. { Heat of evaporation .. kcal.						565,250	565,250	565,250	565,250	565,250
{ Available heat in exit gases .. kcal.						490,750	633,250	778,750	927,250	1,078,750
{ Temp. t_g of exit gases for $\lambda=1.2$.. deg. C.						350	440	510	575	640
$b=40$ per cent. { Heat of evaporation .. kcal.						615,230	615,230	615,230	615,230	615,230
{ Available heat in exit gases .. kcal.						440,770	583,270	728,770	877,270	1,028,770
{ Temp. t_g of exit gases for $\lambda=1.2$.. deg. C.						310	390	460	530	595
Distribution of total losses, a										
Loss in clinker, a_1 per cent.						1.63	1.50	1.40	1.30	1.22
Loss from cooler, a_2 ($Q=200$) "						2.52	2.26	2.05	1.87	1.72
Loss from kiln and residual loss "						13.85	13.24	12.55	11.83	11.06

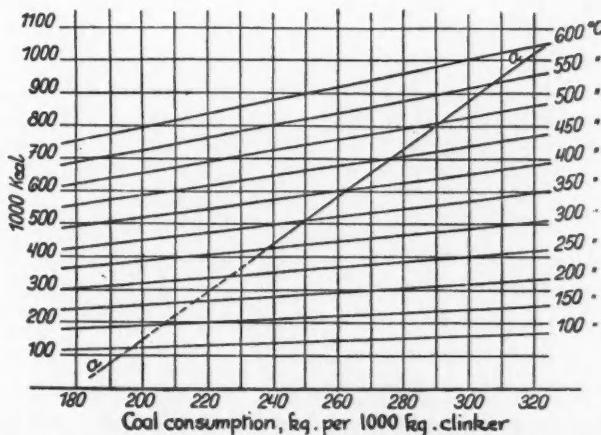


Fig. 11.—Heat Content of Exit Gases and Exit Gas Temperatures.
Wet Process, $b = 36$ per cent.

evaporation of the water in the slurry alone. In addition, there is the heat necessary to superheat the steam formed to the exit gas temperature t_g , amounting, for example, to 196,700 kcal. in the case $x = 260$, $t_g = 440$ deg. C. In this instance, therefore, the steam carries away 761,950 kcal. per 1,000 kg. clinker, which corresponds to 39 per cent. of the fuel used. For the normal unforced rotary kiln of to-day, x is at least 240, for which the exit gas temperature will lie between 400 and 310 deg. C., depending on the water content of the slurry. It is obvious that considerable heat economy would result, and x_{min} would be reduced, if the heat exchange in the slurry evaporating zone were improved and the temperature of the exit gases correspondingly lowered. Values for the possible saving of heat resulting from such measures can readily be obtained as follows.

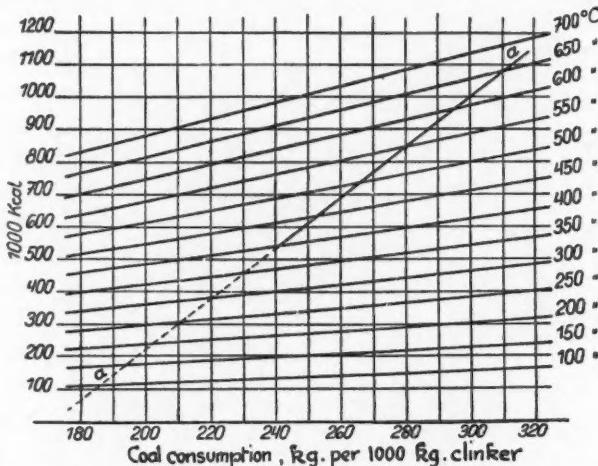


Fig. 12.—Heat Content of Exit Gases and Exit Gas Temperatures.
Wet Process, $b = 40$ per cent.

Let a curve be drawn (Fig. 11) connecting x (abscissæ) with the values of available heat in the exit gases obtained from Table XVI (ordinates). On the same diagram let a series of curves be drawn showing the heat content of the gases at exit gas temperatures rising in steps of 100 deg. C. This series of curves cuts the first curve in a number of points which correspond to x_{min} for the respective temperatures. Figs. 11 and 12 show such diagrams for $b = 36$ and 40 per cent. respectively. In this way the figures given in Table XVII are obtained, which make it clear that considerable economies may be expected from attempts of this kind.

TABLE XVII.
VALUES OF x_{min} IN THE WET PROCESS, FOR VERY LOW EXIT GAS TEMPERATURES, t_g .

Exit gas temperature, t_g	deg. C.	100	125	150	175	200
x_{min} for $b = 36$ per cent.	kg.	185.5	189.5	193.5	197.5	201.5
" " $b = 38$ "	"	190.2	195.0	199.0	203.5	208.0
" " $b = 40$ "	"	196.5	201.2	206.0	211.0	216.0

The constructive measures proposed to bring about this result range over structures of the most various kinds in the evaporating zone, the object of which is to spread the slurry over the maximum possible surface and thus increase the

heat exchange. However, no fixed construction can give the required result, since sooner or later the surface becomes encrusted over, and the crust grows increasingly, and can finally stop up the entire cross-section of the kiln. On the other hand, movable bodies, such as the chains shown in Fig. 13, give very good results when they are sufficiently closely packed and extend over a sufficient length of the kiln.

In practice the most that can be hoped for is to attain an exit gas temperature of 175 to 200 deg. C., depending on the water content of the slurry, so that $x=200$ to 220 kg. approximately. From Table XV, which refers to moist raw meal containing 10 per cent. water, the exit gas temperature for $x=200$ is as much as 715 deg. C. If the chains in the wet process be arranged so that the material leaving the last chain still contains 10 per cent. of water, the gases impinging on this chain will have the temperature 715 deg., and this may be considered to be the limiting temperature if the chains are to have a satisfactory long life.

A further possibility consists in removing the greater part of the water of the slurry by filtration before it enters the kiln. In view of the large quantities of

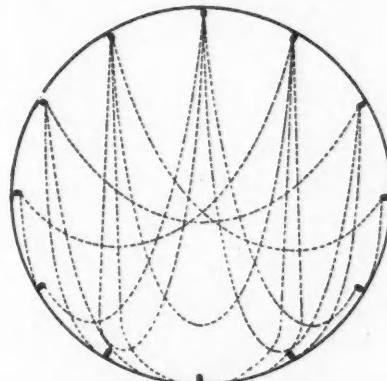


Fig. 13.—Chains.

material to be handled in the cement industry, only continuous rotary filters can be considered for this purpose. The success of filtering is greatly dependent on the nature of the raw materials. Hard limestone and hard marl give a slurry which is easily reduced to a water content of 18 to 20 per cent. with a satisfactory output per unit area of filter surface. With water-soluble marl the filter output is reduced or the residual water content increased. The more colloidal the nature of the raw mix the more unfavourable the conditions, so that the filtration of a mixture of chalk and plastic clay cannot be expected to be economically successful. However, the filtration of cement raw material slurry is only at the beginning of its development, and there is no doubt that a large number of cement works find it advantageous.

In the dry process the possibilities of improving the heat exchange in the kiln and thus attaining lower exit gas temperatures are much less favourable than in the wet process. Here again, however, many types of internal construction have been proposed with this object. But even when these have succeeded in reducing the coal consumption, the exit gas temperature to which they have been exposed

still remained so high that firebrick was the only material of which they could be constructed, and this is, of course, insufficiently resistant to mechanical shocks. Once such constructions begin to wear, their deterioration is accelerated, since the heat exchange becomes worse, the fuel consumption is increased, and the exit gas temperature rises.

An entirely new method, only recently developed, is the Polysius-Lellep process. In this process a very short rotary kiln is coupled with a preliminary plant in which the raw materials are prepared for final burning. Fig. 14 shows the general scheme. The raw meal from silo (1) is transferred to the small feed silo (3) by the elevator (2). From (3) the meal is uniformly delivered to the rotary drum (4), to which a continuous drip of water is simultaneously introduced. By this means the raw meal is readily obtained as small balls or in granular form.

The granular material passes to a collecting hopper situated above an endless chain grate (5). The gases from the kiln (6) pass along an arch which guides them over the layer of material on the grate. An exhaust fan draws the gases through the layer of material and through the grate, and finally blows them to the stack. Connected to the furnace arch over the grate is a second stack (8), which can be closed by means of a damper. This stack is only used to assist in the early stages of firing the kiln; when the plant is working normally it is closed, so that all the gases from the short kiln must pass through the layer of material on the grate. The plant shown in Fig. 14 is designed for powdered coal firing, but the kiln can also be adapted for liquid and gaseous fuel.

The clinker falls from the rotary kiln into a rotary cooler (9); this is of special internal construction to give the most complete transfer of the heat of the clinker to the air for combustion. Small particles of material which fall through the travelling grate are collected in hoppers and are returned to the raw meal silo by a screw conveyor (10) and an elevator (11).

Experience of an experimental plant of this kind extending over a period of almost a year established that the process was characterised by uniformity and regularity.¹⁵ The results of two 24-hour tests of the plant are given in the following:—

Test number	..	..	..	..	..	I.	II.
Duration of test	..	..	..	..	hours	24	24
Clinker output in 24 hours	..	..	..	..	tons	92.8	112.3
Standard coal consumption, x (kg. per 1,000 kg. clinker)	..	..	..	..	kcal.	135.4	143.6
Heat consumption per 1,000 kg. clinker	..	..	..	..		1,015,370	1,076,650
Moisture in granular raw material	..	..	..	..	per cent.	13.8	13.8
Water evaporated per 1,000 kg. clinker	..	..	..	..	kg.	248.1	248.1
CO ₂ content of gases at exhaust fan	..	..	..	..	per cent.	20.3	17.7
Excess air factor at fan (λ)	..	..	..	..		2.0	2.3
Gas temperature at fan	..	..	..	..	deg. C.	109	107
Temperature of clinker leaving cooler	..	..	..	..		331	429
<i>Heat Balance.</i>							
Theoretical heat consumption	..	..	..	..	kcal.	420,000	420,000
Heat for evaporating water	..	..	..	..		147,620	147,620
Available heat in exit gases	..	..	..	..		103,900	117,550
Residual heat in clinker	..	..	..	..		69,500	95,700
Radiation, conduction, etc.	..	..	..	..		274,350	295,780
Total heat consumption	..	..	..	..		1,015,370	1,076,650

¹⁵ O. Lellep. Thermal investigation into the heat consumption in cement-burning. Doctorate thesis at the Technical High School of Brunswick.

TABLE XVIII.
HEAT BALANCES FOR BLAST FURNACE CEMENTS.

Coal consumption,	x kg.	180	200	220
Heat consumption..	kcal.	1,350,000	1,500,000	1,650,000
Total losses, α	per cent.	26	25	24
Theoretical heat requirement	kcal.	270,000	270,000	270,000
Total losses, α	"	351,000	375,000	396,000
Total heat in exit gases	"	729,000	855,000	984,000
Heat of evaporation of water, $b=10$ per cent.	"	91,600	91,600	91,600
Available heat in exit gases	"	637,400	763,400	892,400
Exit gas temp. t_g for $\lambda=1.2$	deg. C.	790	865	925

Although the plant was an experimental one, constructed for economy from materials ready to hand, the results were extremely favourable. In test No. I the output was that for which the plant was designed, but in test No. II the plant was deliberately forced to enable this condition to be studied. The results show that it will not be difficult to effect further improvements, and that a standard coal consumption less than 130 kg. per 1,000 kg. clinker is capable of attainment.

When the rotary kiln is used for burning blast-furnace cement, high exit-gas temperatures are obtained for a relatively low fuel consumption, since the theoretical heat consumption is much smaller. Table XVIII gives heat balances

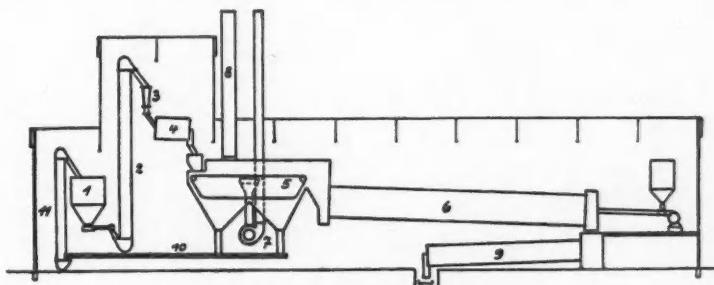


Fig. 14.—Polysius-Lellep Process.

derived on the basis 1,385 kg. raw meal = 1,000 kg. clinker, with the evolution of 385 kg. CO_2 . The calculated theoretical heat requirement is 270,000 kcal. per 1,000 kg. clinker. The total losses, α , must in this case be higher than for normal Portland cement.

(To be continued.)

Cement Prices in Switzerland.

It is reported that cement prices will be increased from 305 francs (£12 1s. 10d.) to 445 francs (£17 13s. 10d.) per ten tons from June 24.

Change of Address.—We are informed that the Green Island Cement Company's new cement works in Hong Kong having been completed, Mr. Henry Pooley, Junr., has been retained as the company's consulting engineer. Mr. Pooley is returning to England, where his address in the meantime will be: C/o Messrs. Withy & Pooley, Swindon (telegrams and cables, "Cimentavis, Swindon").

The Cement Industry in 1930 and 1924. CENSUS OF PRODUCTION FIGURES.

A PRELIMINARY report on the Cement Trade in connection with the 1930 Census of Production has now been issued. Detailed returns were not required from firms employing ten or fewer persons in 1930, and the particulars given for that year relate to firms employing more than ten persons on the average. The particulars given for the year 1924 relate to all firms in the United Kingdom, but this inclusion of the production of Northern Ireland and of small firms in Great Britain hardly affects comparisons between the figures for the two years. The figures for 1930 relate to eighty-four establishments at which operatives were employed; returns are outstanding from establishments that employed, in 1924, about one hundred persons, or less than 1 per cent. of the total number recorded for that year by all firms.

The majority of cement manufacturers own the quarries and workings from which their supplies of limestone and chalk are obtained, and in the Census of 1924 one return covering both the cement works and the quarries was accepted from such firms. In 1930 separate returns were required for the quarry and the factory, and firms were instructed to include in the statement of cost of materials used in cement manufacture the value of the minerals raised at their quarries and transferred for use at the cement works. The effect of this change in method is that the total number of employees returned on schedules for the cement trade for 1924 is higher than the corresponding total shown for 1930 to the extent of the number of persons employed in the firms' own quarries. The amount shown as cost of materials for 1930 is greater, and the net output of the trade correspondingly less than would be shown on the basis adopted for 1924, since the full costs of production at the quarry are included in the statement of materials used in 1930, instead of the cost of materials alone as in 1924.

Production.

Table I shows the values and, where recorded, the quantities of cement produced in 1930 and 1924. The production of all classes of cement in 1930

TABLE I.

Cement.	1930.		1924.	
	Quantity.	Value.	Quantity.	Value.
	Th. tons.	£'000.	Th. tons.	£'000.
Cement for building and engineering purposes	4,943.2	7,346	3,212.6	6,839
Cement for other purposes .. {	6.9	30	3.0	26
	*	149	*	60
TOTAL VALUE	—	7,525	—	6,925

shows a substantial increase over production in 1924, the increase in the case of cement for building and engineering purposes being nearly 54 per cent. The value of the output of cement returned for 1924 by firms that made their returns on schedules for other trades was £167,000.

Prices.

The average selling value of cement for building and engineering purposes was £1.49 per ton in 1930, or about 30 per cent. lower than the average of £2.13 per ton for 1924.

* Quantity not stated.

Exports and Retained Imports.

In Table II exports and net imports of cement in 1930 and 1924 are shown in relation to the quantities manufactured in the two years. The 1930 figure of production relates only to firms in Great Britain that made returns on schedules for the cement trade, and employed more than ten persons in the year, while that for 1924 relates to all firms in the United Kingdom, including small firms and those that made returns on schedules for other trades. The inclusion of these additional returns makes no significant difference to the comparison. The overseas trade figures relate to the United Kingdom in both years.

TABLE II.

Cement.	1930.	1924.
	Th. tons.	Th. tons.
Cement for building and engineering purposes :—		
Production	4,943.2	3,281.4
Exports	1,039.9	651.2
Retained imports	224.7	160.3
Available for use in the United Kingdom .. .	4,128.0	2,790.5
	Per cent.	Per cent.
Share of home market held by British cement ..	94.5	94.3

Cost of Materials and Net Output.

The following figures show the total cost of materials used, together with their net output :—

	1930. £'000.	1924. £'000.
Cost of materials used	3,440	3,172
Net output	4,637	4,899
Net output per person employed	417	361

Employment.

The average number of operatives (apart from administrative, technical, and clerical staff) was 12,522 in 1924, and 9,859 in 1930. Of these there were 268 females in 1924, and 139 females in 1930. The total administrative, technical, and clerical staff increased from 1,068 in 1924 to 1,253 in 1930.

As already explained, the majority of cement manufacturers made combined returns for 1924 covering both cement works and quarries, the staff required to operate the quarries being included in the number of persons employed. At the 1930 Census separate returns in respect of all quarries were made, and, in order to arrive at a correct comparison, it is necessary to add to the total number shown for 1930 the average number employed at quarries owned by cement manufacturers, viz., 2,275, of whom 2,196 were operatives. The decrease in employment between the two census years was thus less than 2 per cent.

The output of cement for building and engineering purposes accounted for 91 per cent. of the total value of the output in 1930, and to somewhat under 85 per cent. in 1924. The average tonnage of such cement produced per operative employed (including those employed at quarries) was, in 1924, little more than three-fifths of that recorded for 1930 (257 tons compared with 410 tons), so that a very important increase in the output per head has been achieved.

Power.

Tables III, IV, and V show the capacity of (a) prime movers, (b) electric generators, and (c) electric motors, at the factories to which the foregoing particulars relate.

TABLE III.

(a) Prime Movers.	1930.	1924.
Reciprocating steam engines :	H.P.	H.P.
Ordinarily in use	10,509	28,825
In reserve or idle	2,625	2,535
Steam turbines :		
Ordinarily in use	38,815	26,060
In reserve or idle	17,825	11,130
Other prime movers :		
Ordinarily in use	9,638	18,396
In reserve or idle	6,253	3,480
TOTAL { Ordinarily in use ..	58,962	73,281
{ In reserve or idle ..	26,703	17,145

TABLE IV.

(b) Electric Generators driven by	1930.	1924.
Reciprocating steam engines :	Kw.	Kw.
Ordinarily in use	3,605	7,622
In reserve or idle	1,816	2,132
Steam turbines :		
Ordinarily in use	28,811	18,400
In reserve or idle	12,800	7,800
Other prime movers :		
Ordinarily in use	4,423	5,952
In reserve or idle	3,623	1,189
TOTAL { Ordinarily in use ..	36,839	31,974
{ In reserve or idle ..	18,239	11,121

TABLE V.

(c) Electric Motors driven by	1930.	1924.
Electricity generated in own works :	H.P.	H.P.
Ordinarily in use	46,379	46,646
In reserve or idle	3,627	5,010
Purchased electricity :		
Ordinarily in use	96,765	18,138
In reserve or idle	8,594	3,553
TOTAL { Ordinarily in use ..	143,144	64,784
{ In reserve or idle ..	12,221	8,563

Important decreases in prime movers, other than steam turbines, and in the capacity of electric generators, except those for which the steam turbines provided the motive power, are shown by these summaries, together with increases in the proportion of idle plant. The decrease in other sources of power in use was more than made good by the increase in electric motors driven by purchased energy.

Electricity Used.

The total quantity of electricity used in 1930 for all purposes at the factories to which this report relates was returned as follows: Electricity generated at firms' works, 110.4 million kilowatt-hours; purchased electricity, 282.5 million kw.-h.; total, 392.9 million kw.-h.

Cement Companies' Dividends and Reports.

Associated Portland Cement Manufacturers, Ltd.

In the course of his speech at the annual general meeting of the Associated Portland Cement Manufacturers, Ltd., held on April 13th, Mr. P. Malcolm Stewart (Chairman) said the profit on trading for the year, at £668,386, showed an increase of £133,605, while the interest and dividends earned were £355,622. The total revenue for the year was £1,024,712, an increase on last year's figure of £69,562.

The outstanding event of the year was the acquisition of the Red Triangle Group embraced by the Allied Cement Manufacturers, Ltd., and its subsidiary companies. Their aggregate capacity approximated 1,000,000 tons per annum and their average deliveries for the last two years 800,000 tons, nearly all of which was sold in the home market. These purchases by the Allied Company had been financed by successive issues of shares, some at substantial premiums. Now and again a solitary voice uttered words of warning, but these were drowned in the chorus of general applause. Few paused to consider whether the prices paid and the financial foundations were sound and whether there was any policy based on practical experience. Those who realised the lack of these essential factors could but wait on events and watch the creation of a weapon which was to prove destructive to the stability of an organised industry and disastrous to the unfortunate shareholders who helped to forge it. The substantial tonnage purchased, however, was not the limit of the ambitions of those concerned. It became clear that the objective was the control of the Associated Company which with its resources and ramifications presented to the imaginative mind a rich prize. Not for the first time did such effort fail, and the risk of being evolved in the debacle which overcame the Allied Company was avoided. How did their Associated Company meet the changed conditions with which it was confronted? Co-operation on terms already enjoyed by the majority of the industry was proffered, but proved impracticable. The only alternatives were to fight the competition or to sit down and see their home trade dwindle away. They did not hesitate to face the issue. Years of work to obtain efficiency should not be sacrificed by loss of turnover and goodwill. Their ample financial resources and the strength of their manufacturing and marketing organisations not only brought them safely through this trying time but left them well equipped to deal with the situ-

ation when a Receiver for the Allied Company was appointed. They paid a fair price for the assets, and given fair trading conditions they should turn the purchase to advantage.

During the year under review trading had been carried on under difficulties of a varied character. The aggregate deliveries of Blue Circle Portland cement in all markets were but slightly below those of the previous year. It was inevitable that they should feel the effects of the world crisis, and the tonnage exported showed a heavy decrease. Deliveries in the home market were expanded, but the selling prices were reduced by the undercutting of the standard prices which had remained in force although they had not been maintained. These standard prices, the reasonableness of which no fair minded person would challenge, were forced down to unsatisfactory levels. It was not to be expected that the unduly low prices which had helped to bring the second largest manufacturing group in the country into difficulties would be allowed to continue without any effort being made to improve them. At the end of September last cement manufacturers resolved to re-establish prices on a fair plane, and this was done by the restoration of prices generally 2s. per ton below the standard. They had never been in favour of high prices; on the contrary they were anxious to increase further the uses of cement by establishing the lowest prices compatible with the maintenance of a sound balance-sheet and a fair return to the shareholders. The policy of factory concentration had enabled them to make successive reductions in costs of manufacture, and this had been passed on to the consumer. The total cost of production had come down from 100 in 1925 to 72 per cent. in 1931, a reduction of 28 per cent. over the seven years. In 1931 the average selling price per ton was only 64 per cent. of the price in 1925, a reduction of 36 per cent. The fact was they had got down to a point where they were giving away rather too much. Last year the margin of profit earned per ton was approximately one-half of that earned in 1925.

Major-General Sir Philip A. M. Nash, K.C.M.G., C.B. (vice-chairman), said the company was particularly fortunate in the strength of its administrative personnel, an asset which could not be shown at its full value on the face of a balance-sheet, and it was fortunate in possessing as chairman a man of such outstanding business ability and one who was so effective in his powers of leadership.

British Portland Cement Manufacturers, Ltd.

In their report for the year 1931 the Directors of the British Portland Cement Manufacturers, Ltd., say that an increased tonnage of Portland cement was sold last year in the home market. The total revenue amounted to £738,147, compared with £731,948 for the previous year. The Directors recommend the payment of a final dividend of 10 per cent. on the Ordinary shares, making 15 per cent. for the year, the same as in 1930.

The sum of £250,000 has been placed to general depreciation reserve, and £5,000 to barge depreciation account, both as last year. In addition, £49,441 has been provided for the Debenture stock sinking funds. The net profit for the year was £354,358, compared with £348,123 in 1930 and £337,817 in 1929.

At the general meeting of the Company held on March 31, Mr. P. Malcolm Stewart (Chairman) said this year the company showed a new item in the balance-sheet—reserves for taxation and contingencies, £163,500—these having been separated from sundry creditors and credit balances. These reserves were available after providing for the liability for taxation to December 31, and the knowledge of their existence would, he was sure, give the shareholders as much satisfaction as it did to the directors. Additions to the fixed assets amounted to £123,622, mainly incurred in the completion of the reconstruction and extension programme. Despite this expenditure the fixed assets at £3,383,262 showed a reduction of £181,971 on last year's figure, brought about by the writing off of depreciation reserves and sinking funds amounting to £305,592. Stock-in-trade showed a reduction of £66,828. The total of cash, Treasury Bills and investments in marketable securities amounted to £913,598; thus the company's financial position was strong and could easily provide its proportion of the new capital required to finance the extensions at the works in India and South Africa in which it had a substantial interest.

The profit on trading and interest and dividends on investments together amounted to £738,015, i.e., £6,176 in excess of last year. There was an increased revenue from interest and investments and also from sundry manufactures which were subsidiary to Portland cement. These gains helped to offset the lower selling prices realised: further, they effected satisfactory reductions in the cost of manufacture made possible by the substantial expenditure on capital account in recent years. They also again benefited by making record deliveries of Portland cement. The profits earned, after making reserves for taxation, permitted the provision of £255,000 for de-

preciation reserves, £49,441 for the service of the Debenture stock sinking funds, the payment of a final dividend of 10 per cent. on the Ordinary shares (making 15 per cent. for the year), leaving £1,558 to be added to the amount carried forward, which would then stand at £206,009.

With regard to the prospects for the current year, the present demand was hardly as good as a year ago. It was difficult to make a definite forecast, but he was hopeful that trade would improve as the increased confidence now being experienced became more firmly established.

The retiring directors (the Rt. Hon. Lord Meston, K.C.S.I., and Mr. W. G. Chapman) were re-elected.

Ketton Portland Cement Co., Ltd.

The Directors of the Ketton Portland Cement Co., Ltd., have decided to pay a dividend at the rate of $\frac{7}{12}$ per cent. per annum in respect of the six months ended December, 1931, on the $\frac{7}{12}$ per cent. Participating Preference shares; and an interim dividend of $\frac{2}{3}$ per cent. on the Ordinary shares—both less tax. The dividend in respect of the 6 per cent. Cumulative 1st Pref. shares was paid on December 31 last.

Oxford and Shipton Cement, Ltd.

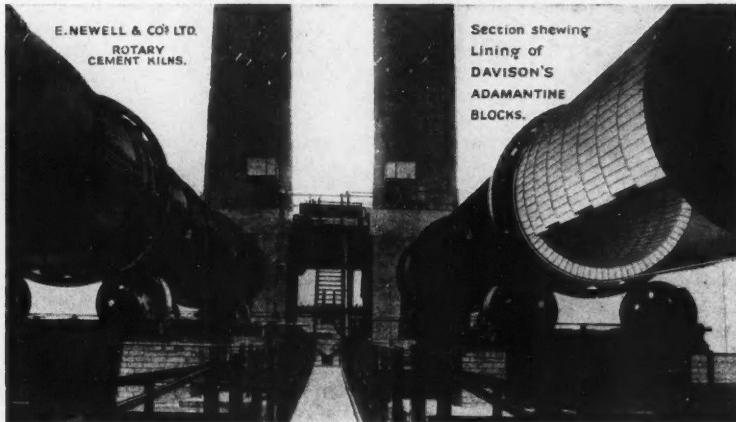
The Fifth Ordinary General Meeting of Oxford and Shipton Cement, Ltd., was held last month, when Mr. A. H. Dillon (Chairman) said the year's working had resulted in a reduction of nearly £20,000 in the amount owing by the company. More than £6,000 was spent during the year on improvements to the works, including provision of an extra locomotive and a steam digger in the quarry, and two additional elevators of large capacity for the conveyance of clinker and cement. At the Kirtlington Quarry a new stone-crushing plant was in course of erection, and it was hoped that the sale of crushed stone for road purposes would be a source of additional profit to the company. The item "Administration, Selling, and General Expenses" at £37,882, was £7,100 less than the previous year, chiefly owing to economies in the sales department. During 1931 the production and sales of cement were slightly higher than during 1930. Though some public and private work had been stopped or suspended, he thought the consumption of cement would be nearly, if not quite, as much in 1932 as in 1931. The company's sales for January and February had been slightly better than for the same months last year.

Eastwoods Lewes Cement, Ltd.

This company has announced an interim dividend of 4 per cent.—as last year—on the Ordinary and Founders shares on account of the year ending June 30 next.

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Notes from the Foreign Press.

Examination of the Kiln Lining of an Arrested Rotary Kiln. By H. Kühl and F. Thilo. *Zement*, Vol. 20, pp. 866, 884, 1931.

Samples of the ring deposits and kiln lining were taken along a 98 ft. rotary kiln of 6 ft. 6 in. diameter after it had been stopped. The kiln lining was of firebrick, 52 per cent. SiO_2 , 43 Al_2O_3 and 2 Fe_2O_3 ; its life was normally six months in the clinkering zone and two years in the other parts of the kiln. When the kiln was stopped the lining in the clinkering zone was only 2 in. thick. No flux had been added to the raw materials.

OBSERVATIONS NEAR THE KILN HEAD.—The slurry feed pipe and the walls of the dust chamber were covered with a red deposit. The material on the feed pipe consisted of iron oxide and sulphate, formed by the oxidation of the tube and absorption of SO_2 from the exit gases. The deposit in the dust chamber consisted of cement dust, coal ash, alkalis, sulphate, and excess quantities of Al_2O_3 and Fe_2O_3 , to the last of which its colour was due. These last two components will be referred to later.

CALCINING ZONE.—In the section 20 ft. to 40 ft. from the kiln mouth the ring had the approximate composition of the cement material. The ring was united to the kiln lining by a lower grey-brown layer and an upper reddish- to yellowish-grey layer. Even where the lining blocks appeared to be unchanged analysis showed them to be increased in CaO content (by 2 per cent.) and decreased in Al_2O_3 (by 3 to 6 per cent.). A sample taken from the ring 40 ft. from the kiln mouth showed that the coal ash had been deposited chiefly in this part, accounting for the high Fe_2O_3 content (5.6 per cent.). A high Al_2O_3 value (14.2 per cent.) in this sample, taken together with that in the dust chamber, indicated the possibility of the transport of Al_2O_3 from one part of the kiln to another by an unknown means. The high contents of alkalis (12 to 19 per cent.) and SO_3 (up to 6 per cent.) in the intermediate layers were noteworthy. It would appear that the alkalis vaporise in the clinkering zone, penetrate the ring material and deposit on the firebrick, absorbing SO_3 from the hot gases to form the intermediate layers; this to a great extent causes the wear of the kiln lining.

CLINKERING ZONE, 13 to 20 ft. from the kiln mouth. In the centre of the clinkering zone, 16 ft. from the exit, the ring is in four layers, viz., at the bottom a grey-black slag, then a pure white layer, then a greenish white layer, and on top a blackish clinker mass. The three lower layers are characterised by very low Fe_2O_3 content and by an increase in alkalis and SO_3 with depth. The possibility of the iron having been distilled away as sulphide must here be considered.

BELLOW THE CLINKERING ZONE.—At the lower end of the clinker-ring, 11 ft. from the exit, the ring was again stratified. The surface layer was a combination of cement and ash enriched with alkalis and sulphur. The middle and especially the lowest layers had extremely high silica (54 per cent.) and alkali (13 per cent.) contents. The high silica content must be considered to be bound up with the high sesquioxide content found in the calcining zone and dust chamber, and some form of iron and alumina (possibly sulphide) distillation must be assumed.

Reddish and black deposits, in part hygroscopic and covered with yellow pyrites crystals, were found between the kiln shell and the lining in and just outside the clinkering zone, and in one instance 10 ft. from the slurry inlet. They consisted essentially of iron oxide and sulphate, and, in the clinkering zone, bisulphide. This deposition of iron between shell and lining may be associated with the disappearance of iron from the white layer of the clinker-ring. The observations in general show that the wear of the kiln lining is not due to



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reactions between cement, coal ash and lining alone, but that gaseous reactions with distillation and condensation must play a part.

Relation between the Technical and Physico-chemical Properties of Cement.

D. WERNER and S. GIERTZ-HEDSTRÖM. *Zement*, Vol. 20, pp. 984, 1000, 1931.

It is shown that the important technical properties of hardened cement are mainly dependent on the extent and manner of combination with water, and that the chemical composition of the cement is of subsidiary importance.

CRUSHING STRENGTH.—The expression $C = 0.305(f - 25)^2$ satisfactorily connects the crushing strength (C) of Portland and aluminous cements with the percentage by volume of the solid phase (f); (f) is calculated as the volume of cement + combined water, as obtained in the recent paper by Giertz-Hedström. The figure 25 in this and the succeeding formulae represents the approximate minimum volume of solid phase when cement is mixed with excess water.

TENSILE STRENGTH.—The expression $T = 0.224(f - 25)^{4/3}$ represents the relation between tensile strength (T) and percentage volume of solid phase in the cement. It is derived from the expression for crushing strength and Feret's equation $T = C^{2/3}$. For this and the succeeding relations the experimental results are not in such good agreement as for the crushing strength formula.

MODULUS OF ELASTICITY.—The expression $E = 254(f - 25)^{5/3}$ approximately represents the relation between the modulus of elasticity of the cement and percentage volume of solid phase.

SHRINKAGE.—A curve is plotted connecting percentage shrinkage with volume of loosely combined water (as defined in the previous paper) expressed as a percentage of the total combined water; this curve does not represent a definite function. The following table gives approximate points on the curve, which is very steep above 40 per cent. water.

Per cent. shrinkage.	Per cent. volume of loosely combined water.
0.01	10
0.03	20
0.13	30
0.3	40
1.0	50

PERMEABILITY TO WATER.—Permeability (due to capillary forces) is plotted against volume of loosely combined plus free water, expressed as per cent. of total water. The following points lie on the curve, which represents no definite function:

Permeability g. per 100 hours.	Per cent. volume of loosely combined + free water.
0	25
2	40
3	50
10	60
23	65

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Recent Patents Relating to Cement.

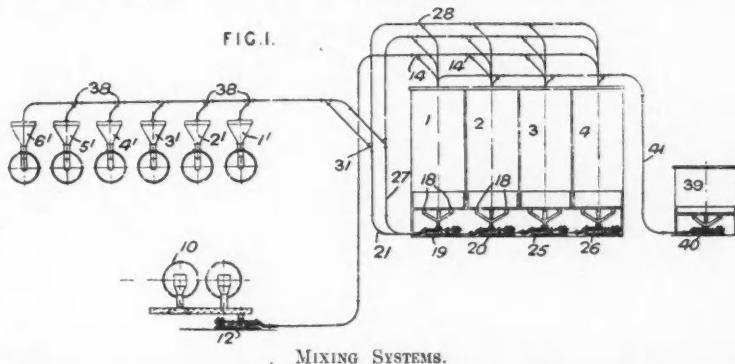
Mixing Systems. FULLER CO., Cata-
sauqua, Pennsylvania, U.S.A. (Assignees
of Morrow, J. H., Catasauqua, Pennsyl-
vania, U.S.A.) August 8th, 1929. No.
338,123.

Pulverulent materials such as raw material for cement, etc., are blended by being fed cyclically to a number of silos, the delivery to each silo being for a predetermined interval during which a thin layer is deposited, the material being withdrawn at a number of points from one or a number of silos and redistributed to the silos, or passed to one of a number of bins. The invention is described with reference to the manufacture of cement, the product from a mill being passed to a number of silos and thence to a number of kilns. The material is fed from the mills (10) by a pump of the kind described in Specification 152,300, and is distributed in thin layers to the silos (1

to 6), the delivery to each silo being controlled by a switch (31) and a valve (32).

Cements. BERRY, H., Woodview, Welwyn, Hertfordshire. April 10, 1930. No. 350,129.

Magnesium or calcium oxide or hydroxide or blast furnace slag or mixtures thereof alone or mixed with base material are heated in the presence of hydrochloric acid. The oxides may be obtained by calcination of natural carbonates. The acid may be added by being introduced into the furnace during calcining or during a reheating of the oxides, either as a solution of the acid or as a solution of a salt of the acid. In addition to hydrochloric acid, sulphur in combination as sulphuric or sulphurous acid and an aluminium salt may be present. An alternative method of introducing the acid, etc., is to dip the oxides after calcining in a solution of the acid and subject to a re-heating.



MIXING SYSTEMS.

. . . 4) in turn. Each silo is fitted with a number of discharge points (18) leading to similar pumps (19, 20, 25, 26), by means of which the material is forced through pipe lines (21, 27), and is either redistributed to the silos or diverted to a number of kiln bins (1' . . 6'). At (39) is a silo which may contain another ingredient such as flue dust, and is fitted with a pump (40) and discharge pipe (41). The pipe lines are fitted with two-way cocks (14, 28, 31, 38) by means of which the distribution of the material to the silos and bins is controlled, and these cocks may be controlled electrically through a barrel switch, the cocks being fitted with mercury switches controlling indicating circuits by means of which the working of the process can be observed. The silos may be fitted with depending vanes the deflec-

Slag Cements. BUDNIKOFF, P. P., Technologichesky Institute, Charkoff, Russia. February 17th, 1930. No. 347,357.

Cement is made from blast-furnace slag by adding thereto, without subsequent burning, (1) anhydrite or gypsum cement, or a mixture thereof, or insoluble anhydrite, or Estrich gypsum, in combination with one or more of the following—chalk (or limestone or marble), dolomite, fluorspar or phosphorite (or calcium superphosphate), or (2) dolomite burned to 500-800 deg. C. combined with insoluble anhydrite or Estrich gypsum with or without the addition of unburned dolomite, fluorspar or phosphorite. In an example granulated slag is ground in a ball mill together with 5 per cent. of Estrich gypsum, 2 per cent. of chalk and 3 per cent. of superphosphate. Other examples are given.

Swiss Cement Companies' Dividends.

Likonia A.G., Basle, has declared a dividend of 6 per cent. for 1931 and a net profit of 394,000 francs (f15,622). This compares with a dividend of 6 per cent. for 1930 when the net profit was 409,347 francs (f16,231).

Holderbank Financiere Glarus A.G. has declared a dividend of 7 per cent. for 1931 and a net profit of 499,891 francs (f19,821) on a capital of 7,250,000 francs (f287,470). This compares with a dividend of 6 per cent. for 1930 and a net profit of 381,391 francs (f15,122) on a capital of 5,000,000 francs (f108,255).

Société des Chaux et Ciments de la Suisse Romande has declared a dividend of 5 per cent. for 1931, compared with 6 per cent. for 1930.

United States Cement Companies' Dividends.

Pennsylvania Dixie Cement Corporation showed a net loss of \$1,358,506 dollars (\$279,527) for the year 1931, and the dividend was again passed.

Lehigh Portland Cement Company reports a net profit of 79,328 dollars (£16,322) for 1931, compared with 2,105,093 dollars (£433,331) for 1930.

Lawrence Portland Cement Company reports a net loss of 443,020 dollars (\$91,156) for 1931, compared with a net profit of 763,302 dollars (\$157,059) and 476,725 dollar (\$98,090) in 1930 and 1929 respectively.

Missouri Cement Company shows a net loss of \$335,353 dollars (\$69,002) for 1931, compared with \$1,205,832 dollars (\$248,113) and \$1,312,987 dollars (\$270,161) net profit for 1930 and 1929 respectively.

Giant Portland Cement Company shows a net loss of 168,102 dollars (34,588) in 1931, compared with a net profit of 111,518 dollars (£22,946) and 84,261 dollars (£17,337) for 1930 and 1929.

South Dakota State Cement Company reports a net loss of \$1,137 dollars (\$234) for the six months July to December, 1931, compared with a net profit of \$4,510 dollars (\$1,216) for January to June, 1931.

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